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ABSTRACT

In light of evidence indicating that errors in making accurate pie charts are prevalent, an alternative method for constructing pie charts is proposed. It involves the use of a simple trigonometric formula to compute a factor of the length of the chord that defines a given percentage sector. This factor is multiplied by the radius of the circle to yield the length of the required chord. The formula, its derivation, and values yielded by it are given. Making approximations using it are briefly discussed. (MNS)

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Trigonometric Insights into Pie Charts

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Running head: Pie Charts

Trigonometric Insights into Pie Charts

In discussions of the use of the pie chart (also called sector chart, circle diagram, pie diagram, and pie graph) as a technique for depicting subgroups of nominal data effectively, some authors who delve into other techniques of visual representation in detail, dismiss the construction of the pie chart as being self-evident, or make passing reference to its construction with a common protractor, percentage protractor, or preprinted percentage circle. In examining 26 pie charts used in varying contexts in a wide range of publications, the authors found no fewer than 16 that contained one or more sectors that were in error in excess of one percentage point (3.6°). There were 48 instances of such errors, with a mean error of 1.8 percentage points (6.5°) per occurrence.

In light of this evidence of the apparent prevalence of such errors, alternate methods for constructing pie charts might be considered. One such method involves the use of a simple trigonometric formula to compute a factor of the length of the chord that defines a given percentage sector. This factor is multiplied by the radius of the circle to yield the length of the required chord; Figure 1 depicts the formula and its derivation.

Insert Figure 1 about here

The actual values for the factor AB yielded by this formula for percentages one through fifty appear in Table 1.

Insert Table 1 about here

The argument might be made that, since the pie chart is primarily a visual device, the sectors do not have to be exact in most informal applications. The technique outlined above can also be useful for making approximations in less formal uses by noting the following patterns in the table:

1) The incremental values of AB for any given 1% increase in sector size range from .0451 to .0628 over percentages from 1% to 25%, with a mean increase of .0566. A fairly good approximation in round numbers is .05.

2) The increments associated with a 5% increase in sector size range from .2386 to .3129 over the same percentages, with a mean increase of .2829. A fairly good approximation in round numbers is .30.

Because of the nature of the underlying trigonometric functions, it is recommended that, for simplicity, when using these approximations, the pie chart constructor not use them directly for percentage values between 25 and 50. Instead, to construct such a sector, subtract 25% from the desired percentage sector and find the two points on the circumference of the circle wnich define the desired sector (i.e., points A and B) by first finding the intermediate point on the circumference which corresponds to

25%, and measuring the residual percentage in the prescribed way to locate the other end of the desired chord. Sectors containing more than 50% can be constructed by considering the "excess" percentage as a residual.

The authors do not presume to think that this technique will revolutionize the construction of pie charts. They do, however, hope that this endeavor will help to sensitize users of such visual aids to the existence of poorly constructed pie charts and add another tool to their arsenals, with which they might construct pie charts more accurately and, on occasion, more easily.

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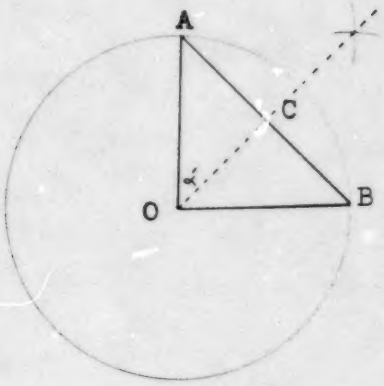
Figure 1



GIVEN: A circle with center O and radius $r=\overline{OA}=\overline{OB}$

X=% sector desired

α=central angle of the desired sector

$\alpha'=\frac{1}{2}\alpha$

FIND: $\overline{AB}$ (the chord that defines the sector X), in terms of r

SOLUTION:

Bisect $\angle AOB$, so that $\angle AOC = \angle BOC = \alpha'$.

Since $\overline{AO} = \overline{BO}$ and $\overline{OC} = \overline{OC}$, $\Delta AOC \cong \Delta BOC$.

Therefore, $\overline{AC} = \overline{BC} = \frac{1}{2}\overline{AB}$ and $\angle ACO = \angle BCO$;

Also, $\angle ACO + \angle BCO = 180^\circ$, so $\angle ACO = \angle BCO = 90^\circ$.

Since $\sin\alpha' = \overline{AC}/\overline{OA}$ and $\overline{OA} = r$, $\sin\alpha' = \overline{AC}/r$.

And, since $\overline{AC} = \overline{BC} = \frac{1}{2}\overline{AB}$, $2(\sin\alpha') = 2(\overline{AC}/r)$,

Or, $2\sin\alpha' = \overline{AB}/r$.

Solving for $\overline{AB}$, $\overline{AB} = r(2\sin\alpha')$.

Table 1

Values for Factor AB and Incremental Differences

for Percentage Sectors from 1% to 50%

Percentage	AB*	Increment**	Percentage	AB*	Increment**
1	.0628	.0628	26	1.4579	.0423
2	.1256	.0626	27	1.5002	.0408
3	.1882	.0625	28	1.5410	.0393
4	.2507	.0622	29	1.5803	.0377
5	.3129	.0619	30	1.6180	.0362
6	.3748	.0615	31	1.6542	.0345
7	.4363	.0611	32	1.6887	.0328
8	.4974	.0606	33	1.7215	.0311
9	.5580	.0600	34	1.7526	.0294
10	.6180	.0595	35	1.7820	.0277
11	.6775	.0587	36	1.8097	.0258
12	.7362	.0581	37	1.8355	.0241
13	.7943	.0573	38	1.8596	.0222
14	.8516	.0564	39	1.8818	.0203
15	.9080	.0555	40	1.9021	.0185
16	.9635	.0546	41	1.9206	.0166
17	1.0181	.0536	42	1.9372	.0146
18	1.0717	.0525	43	1.9518	.0128
19	1.1242	.0514	44	1.9646	.0108
20	1.1756	.0502	45	1.9754	.0088
21	1.2258	.0490	46	1.9842	.0069
22	1.2748	.0478	47	1.9911	.0050
23	1.3226	.0465	48	1.9961	.0029
24	1.3691	.0451	49	1.9990	.0010
25	1.4142	.0437	50	2.0000	

*Factor for the length of the radius which will yield chord

**Computed from next higher percentage